Atmospheric mercury concentrations near Salmon Falls Creek Reservoir - Where is the mercury coming from?

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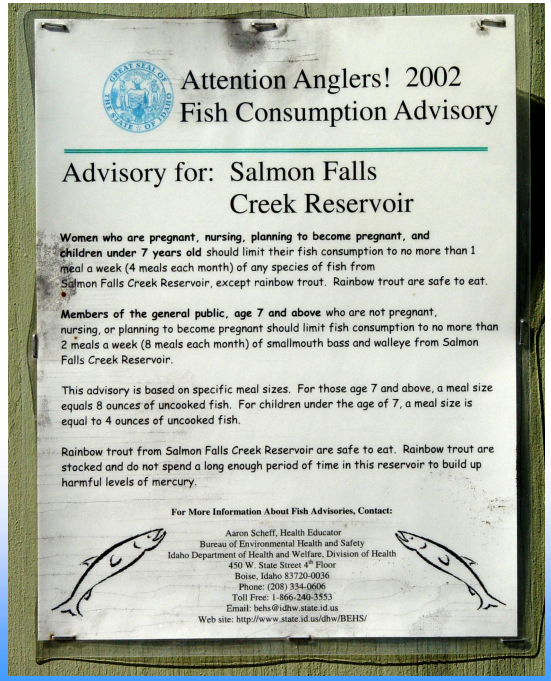
Four lakes in southern Idaho w/ Hg advisories

Salmon Falls Creek Reservoir

Fish Species	Mercury Range *(mg/kg)*	No. of Fish	% above 0.3
Kokanee	0.17 - 0.25	2	0
Rainbow Trout	0.0 - 0.24	11	0
Smallmouth Bass	0.44 - 0.66	2	100
Walleye	0.25 - 1.08	12	92
Yellow Perch	0.2 - 0.48	10	80

- IDEQ began study at SFCR in 2005 – air, water, snow, wet dep, sediment
- What's causing high fish concentrations?
- Our objective – is there an air input and where is it coming from?

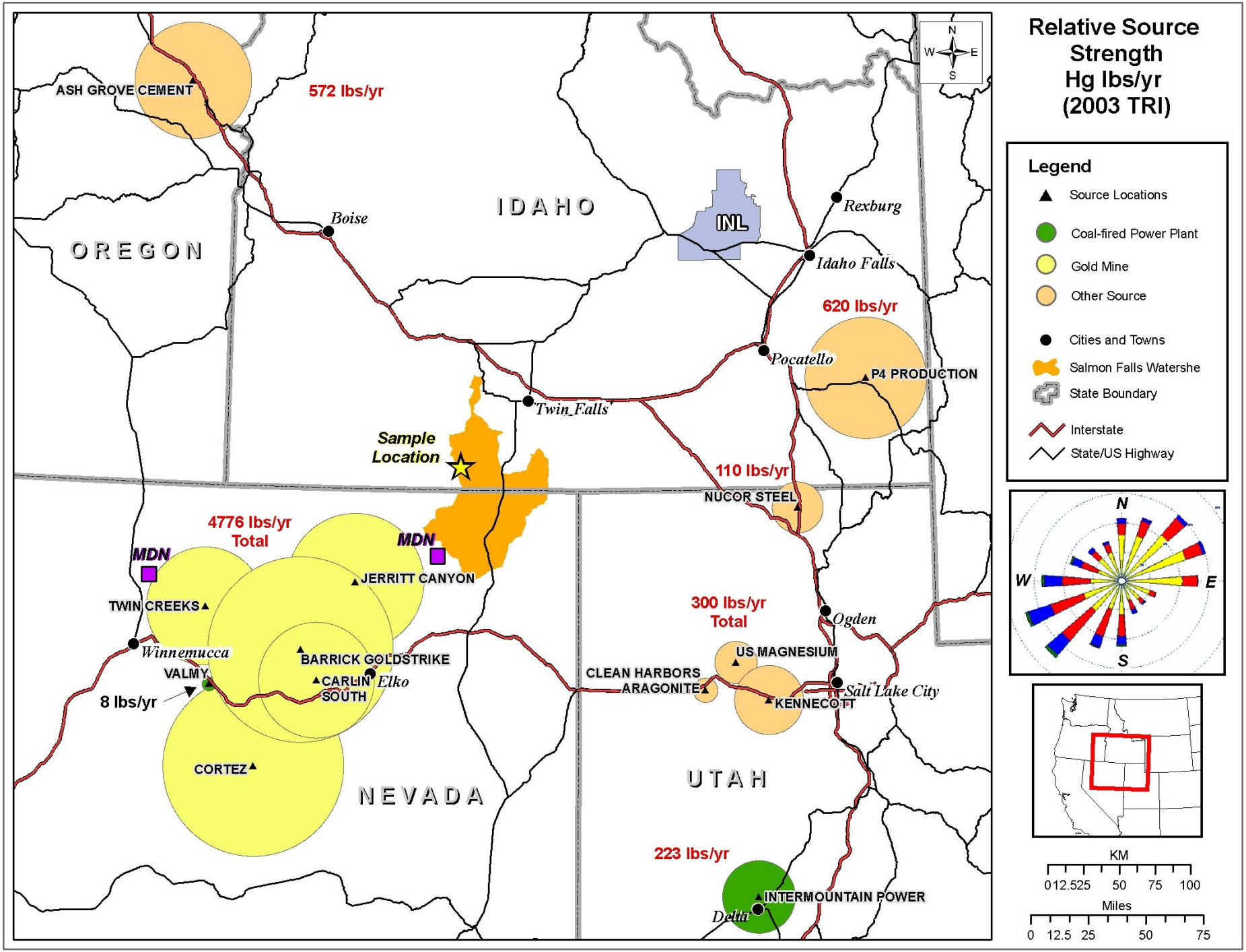


Air Input?

- Elemental gaseous Hg (EGM) - most (99%) of atmos Hg
  - relatively non-reactive, low deposition rate, but some studies suggest it may contribute.
- Reactive gaseous Hg (RGM) and particulate Hg (HgP) - oxidized Hg (mostly Hg^{+2}) - highly reactive and depositing.
  - found locally near sources with RGM/HgP emissions.
  - produced in atmos from O3 and OH oxidation of EGM.
- RGM Wet deposition - MDN-type sampler
  - Two NV sites show sporadic high concentrations in summer (50 to >100 ng/L) , but total annual flux not unusually high (3-4 ug/m^2/y).
- RGM Dry deposition – likely the driver for arid regions
  - no proven direct measurement methods.
  - Estimate using RGM air conc x published deposition velocities.

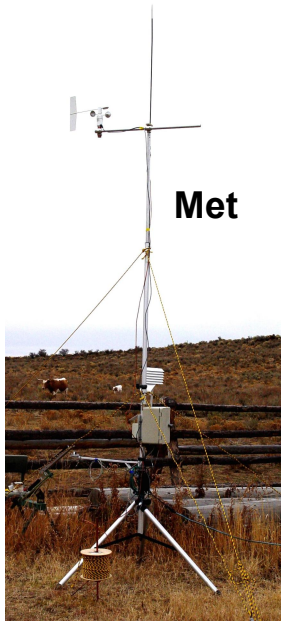
Why measure Hg^0?

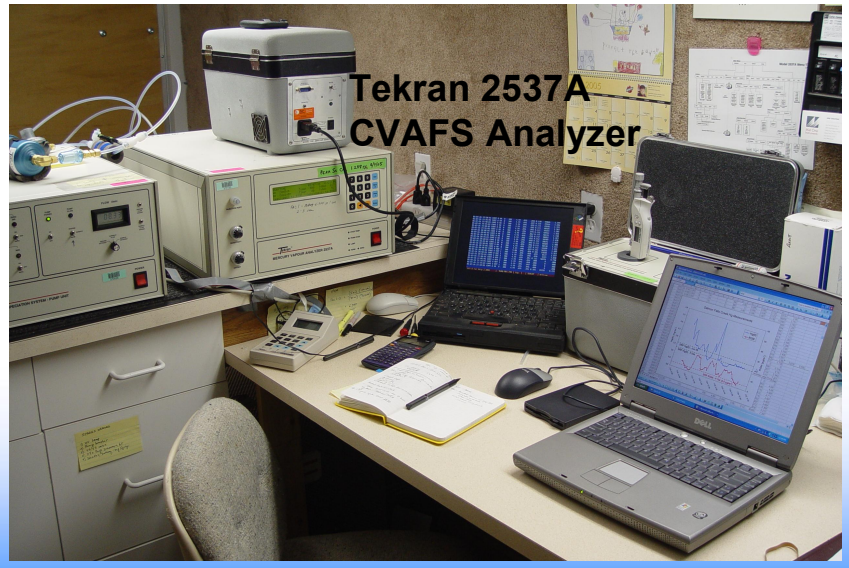
- Prevailing winds in SFCR watershed from NV; most sources in NV, both natural and anthro, emit primarily Hg^0:
  - Evasion from naturally enriched substrates, hydrothermal areas – est. 10,000 kg/y over all of NV (Zenner and Gustin, 2002)
  - Largest anthro sources in NV are gold mines (11) - mostly Hg^0 – 2003 est. 2,200 kg/y; 1998-2003 avg 5,100 kg/y (EPA TRI).
- A major source of Hg^{+2} in remote regions is atmospheric oxidation of Hg^0, esp. in summer when photochemical oxidation rates are high (ozone, sunlight).
- For a given photochemical oxidation rate (RGM/EGM ratio), high Hg^0 will increase local production and deposition of Hg^{+2}.
- Jury still out on EGM deposition – long-term flux chamber measurements needed.


Relative Source Strength Hg lbs/yr (2003 TRI)
Legend
Source Locations
Coal-fired Power Plant
Gold Mine
Other Source
Cities and Towns
Salmon Falls Watershe
State Boundary
Interstate
State/US Highway
N
W
E
S
ASH GROVE CEMENT
572 lbs/yr
IDAHO
OREGON
Boise
INL
Rexburg
Idaho Falls
620 lbs/yr
Pocatello
P4 PRODUCTION
Twin Falls
Sample Location
110 lbs/yr
NUCOR STEEL
4776 lbs/yr Total
MDN
MDN
JERRITT CANYON
TWIN CREEKS
Winnemucca
VALMY
8 lbs/yr
BARRICK GOLDSTRIKE
CARLIN SOUTH
Elko
CORTEZ
NEVADA
300 lbs/yr Total
Ogden
US MAGNESIUM
CLEAN HARBORS ARAGONITE
KENNECOTT
Salt Lake City
UTAH
223 lbs/yr
INTERMOUNTAIN POWER
Delta
KM
0 12.5 25 50 75 100
Miles
0 12.5 25 50 75

This is a remote area!
- no local Hg sources
(nothing but cow dogs on the lookout for coyotes)

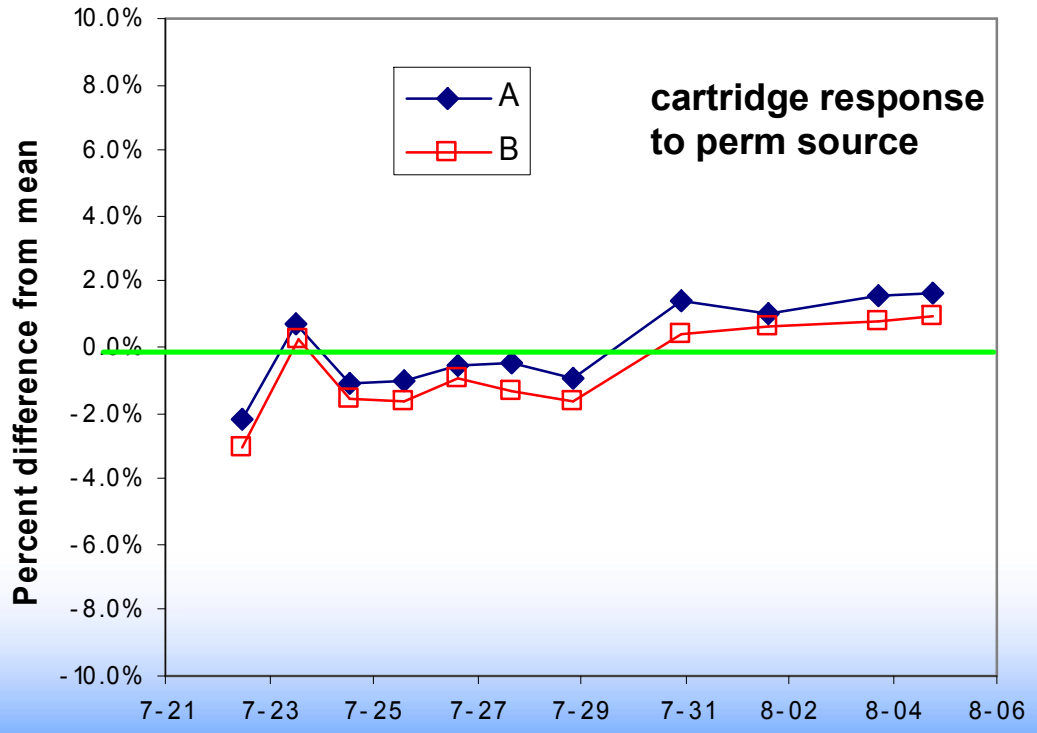
- Speciated EGM, RGM measured w/ INL Tekran 2537A, 1130, 14 day data sets-Jul/Aug and Nov 2005 (in progress)
- NO_2, SO_2, PM-10, and ozone w/ IDEQ instruments
- Met – **WS,WD,AT,RH,SR**

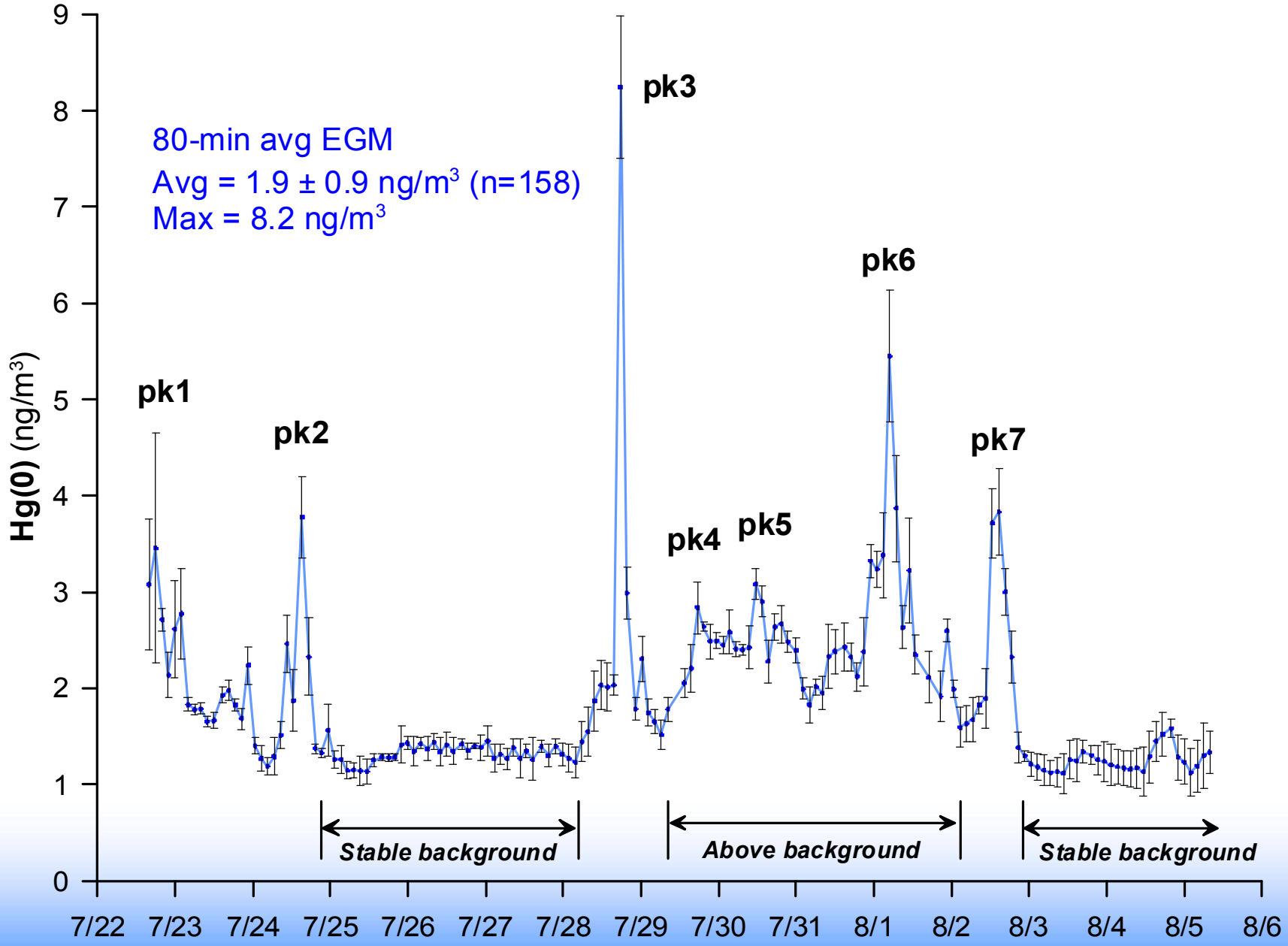


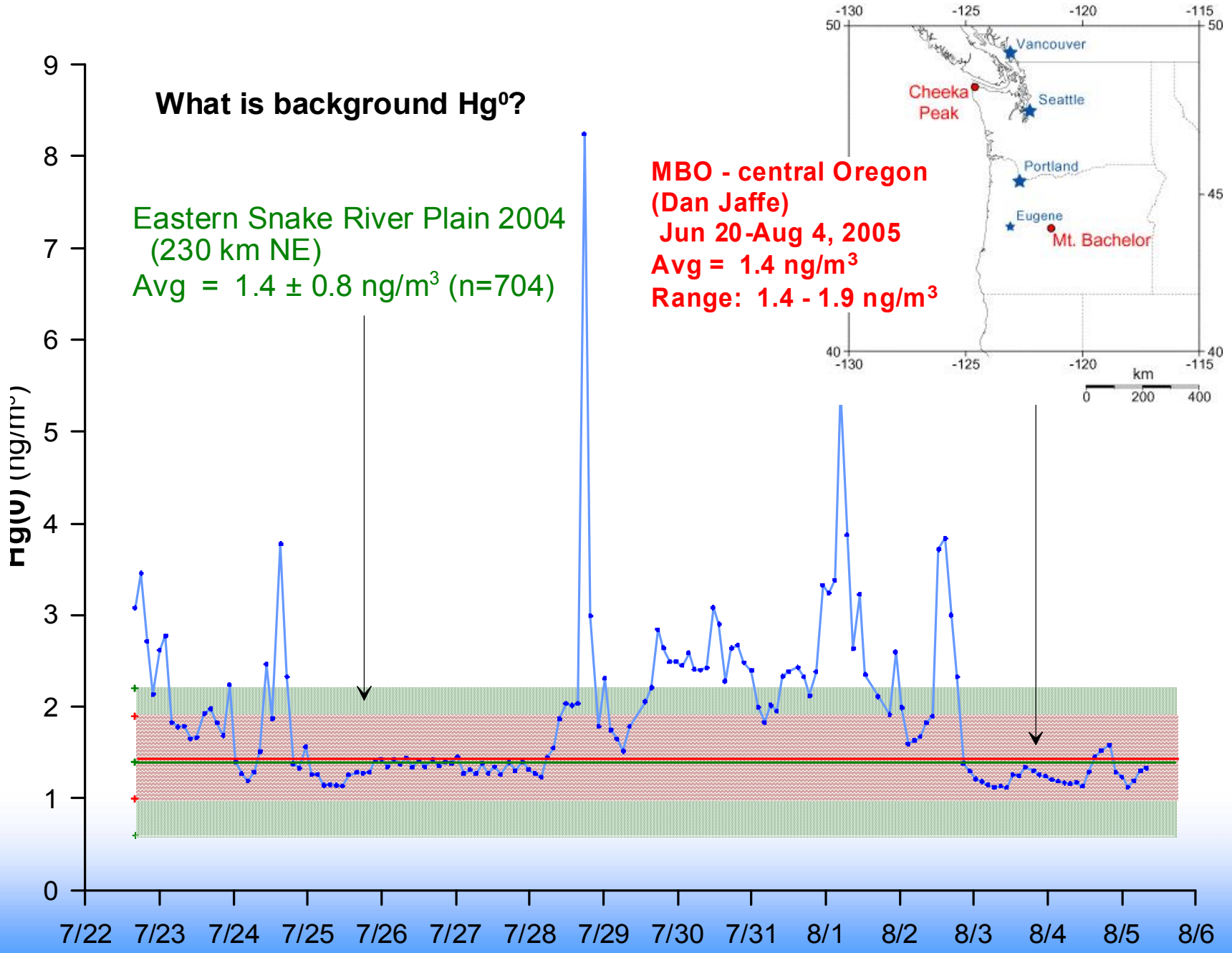


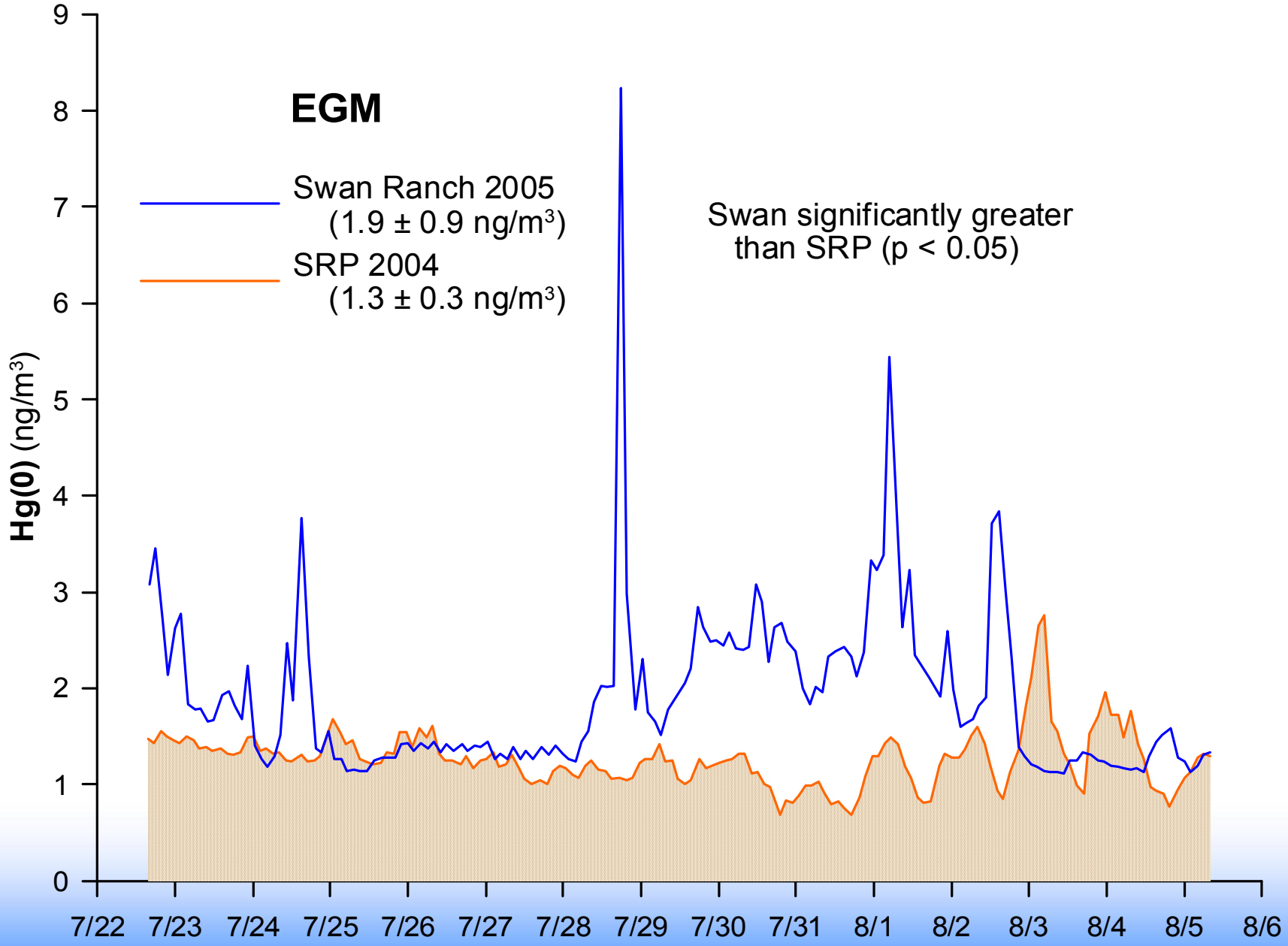
QA/QC

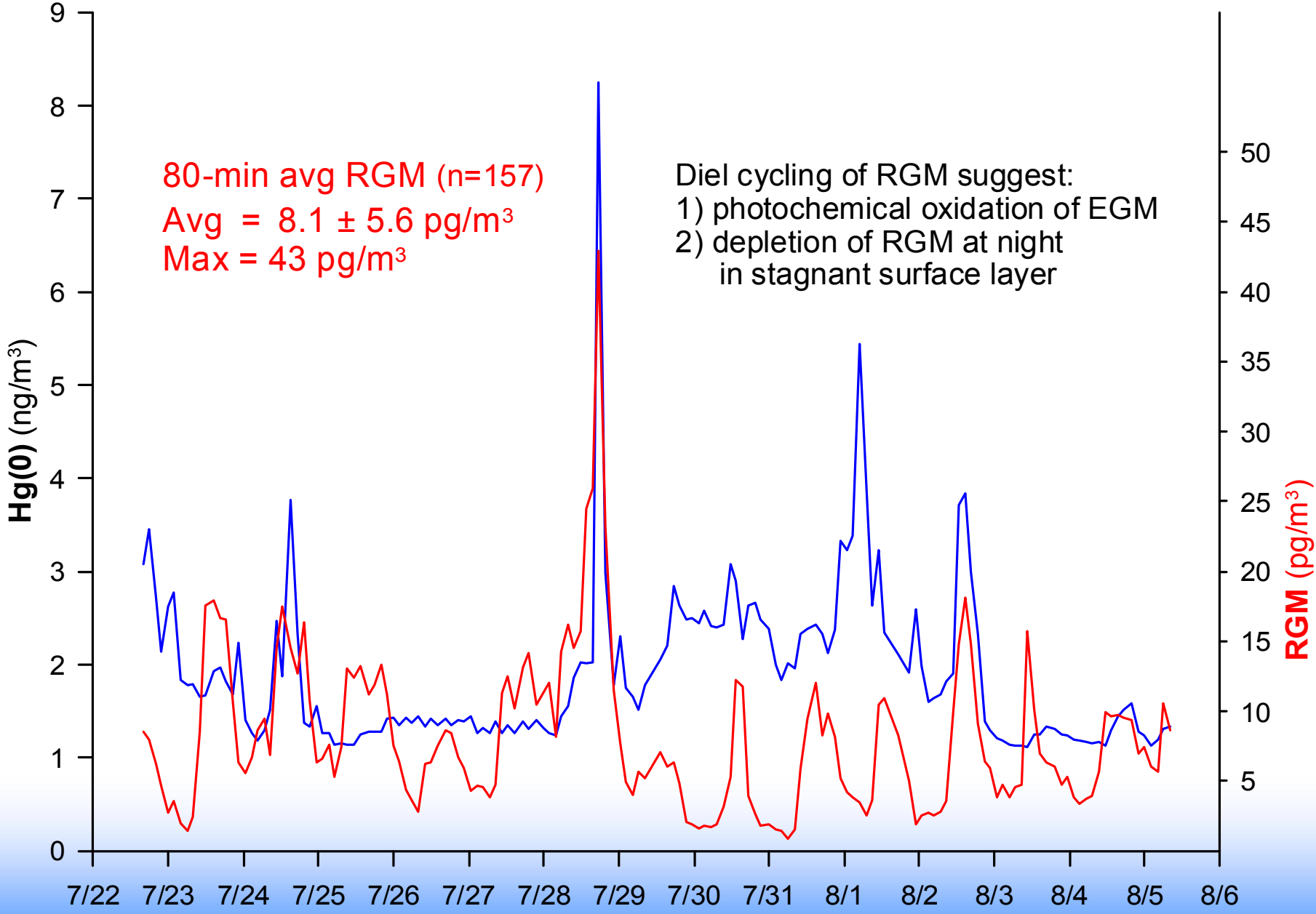
- 6-month Calibration of 2537A using 2505 saturated vapor calib unit (detection limit < 0.1 ng/m^3).
- Standard additions (n=12) prior to deployment (102% ± 6%)
- 2537A mass flow controller calibration (+2%)
- Total system blank check w/ zero air (always 0)
- Total system standard additions w/ vapor injections (95-110%)
- Daily perm source calibrations (± 1.3%)
- Cartridge bias check

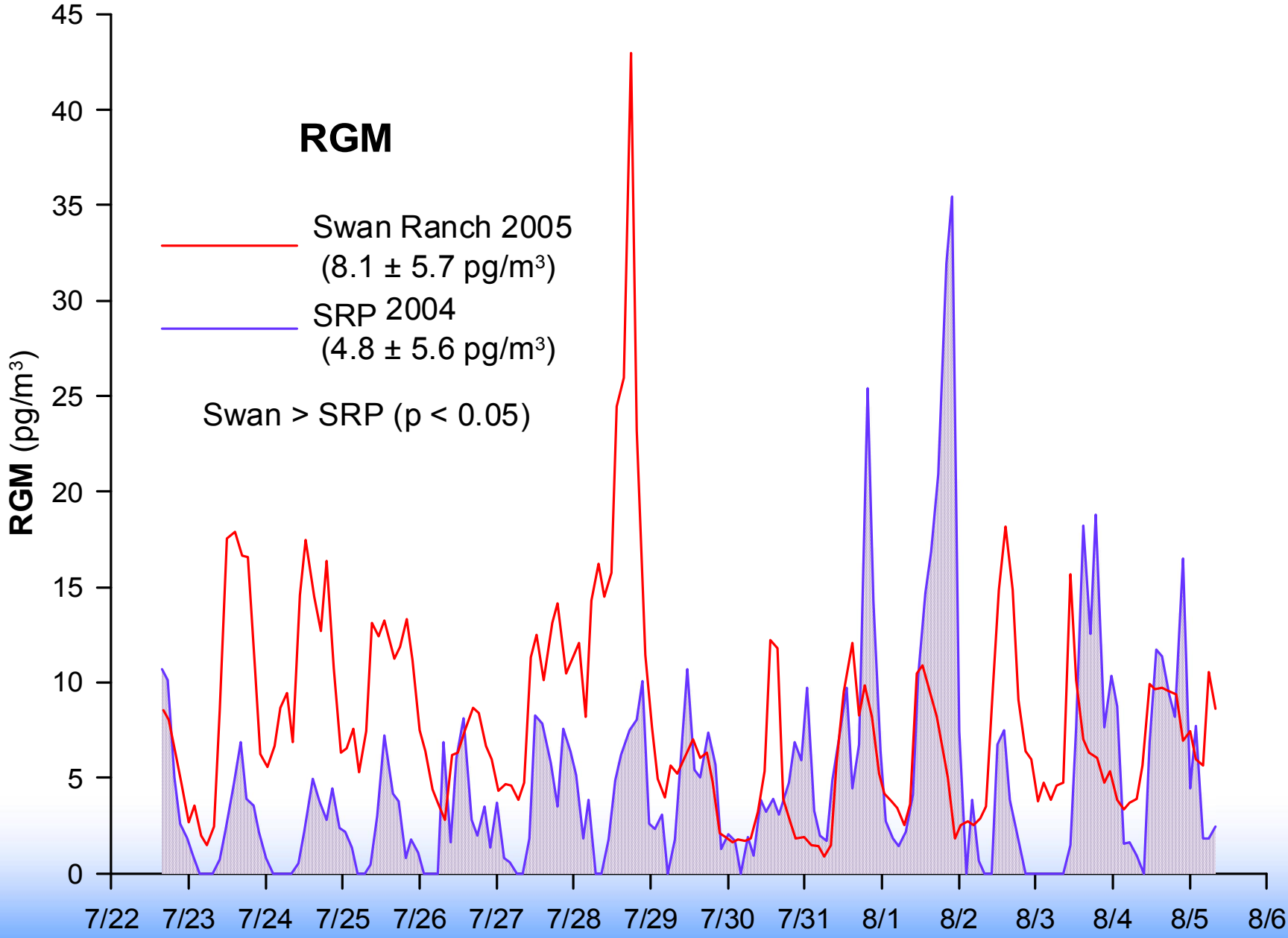


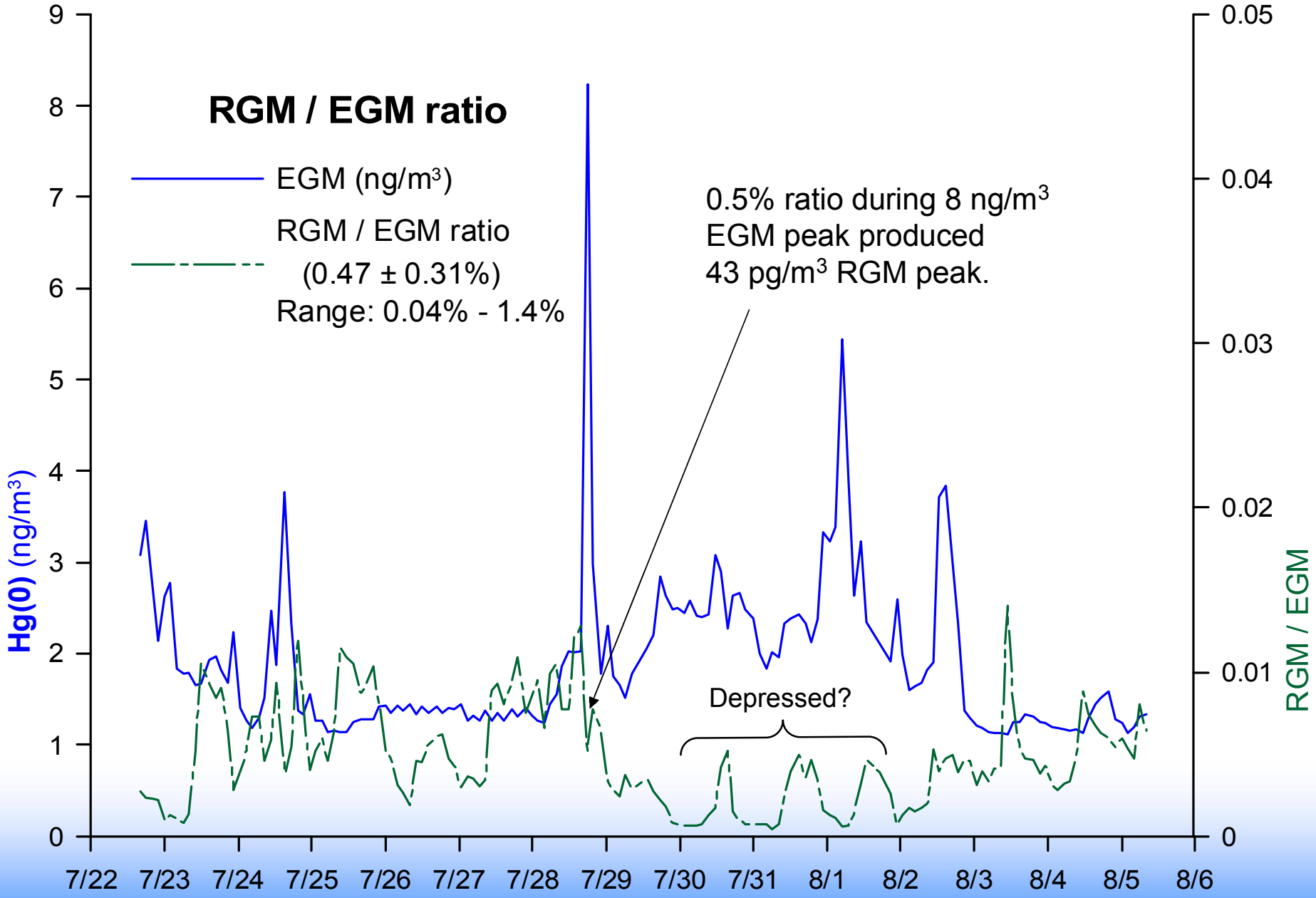

80-min avg EGM
Avg = 1.9 ± 0.9 ng/m3 (n=158)
Max = 8.2 ng/m3
Hg(0) (ng/m3)
pk1
pk2
pk3
pk4
pk5
pk6
pk7
Stable background
Above background
Stable background
0
1
2
3
4
5
6
7
8
9
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6


What is background Hg⁰?
Eastern Snake River Plain 2004
(230 km NE)
Avg = 1.4 ± 0.8 ng/m³ (n=704)
MBO - central Oregon
(Dan Jaffe)
Jun 20-Aug 4, 2005
Avg = 1.4 ng/m³
Range: 1.4 - 1.9 ng/m³
Hg(0) (ng/m³)
0
1
2
3
4
5
6
7
8
9
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6
-130
-125
-120
-115
50
45
40
Vancouver
Seattle
Cheeka Peak
Portland
Eugene
Mt. Bachelor
km
0
200
400

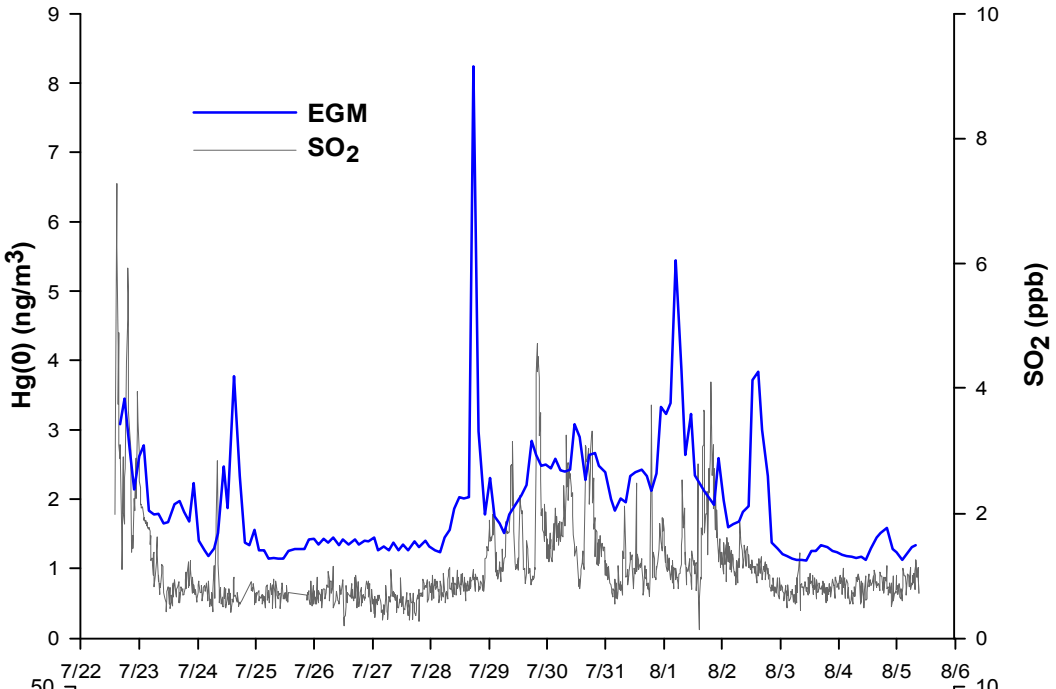

EGM
Swan Ranch 2005
(1.9 ± 0.9 ng/m³)
SRP 2004
(1.3 ± 0.3 ng/m³)
Swan significantly greater
than SRP (p < 0.05)
Hg(0) (ng/m³)
0
1
2
3
4
5
6
7
8
9
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6


80-min avg RGM (n=157)
Avg = 8.1 ± 5.6 pg/m3
Max = 43 pg/m3
Diel cycling of RGM suggest:
1) photochemical oxidation of EGM
2) depletion of RGM at night
in stagnant surface layer
Hg(0) (ng/m3)
RGM (pg/m3)
0
1
2
3
4
5
6
7
8
9
5
10
15
20
25
30
35
40
45
50
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6

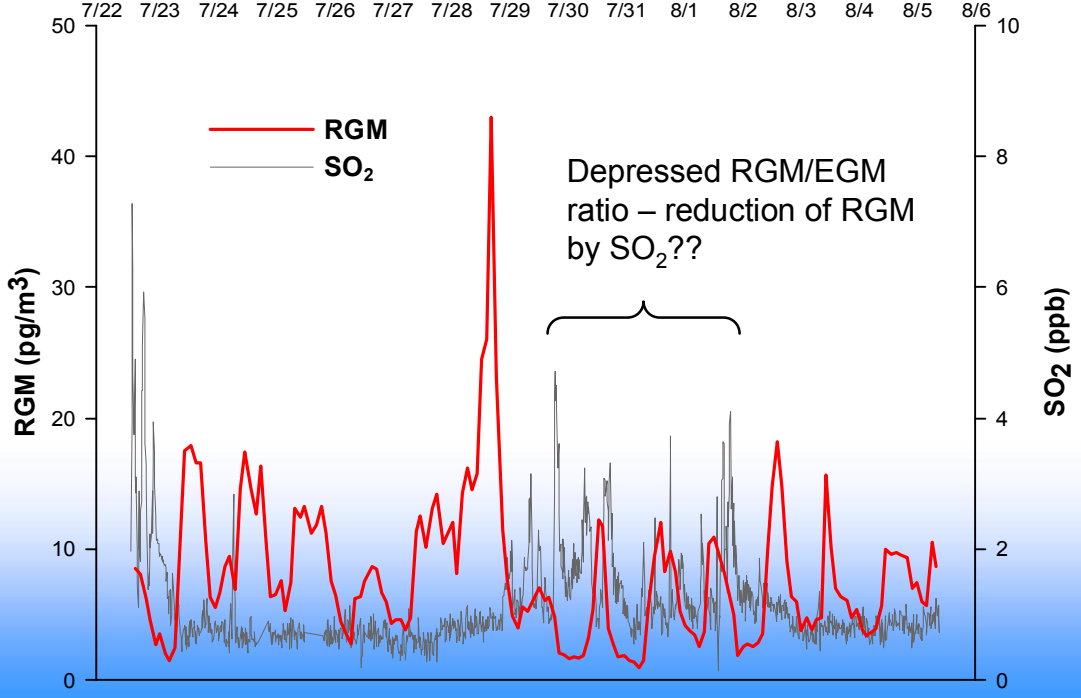

RGM
Swan Ranch 2005
(8.1 ± 5.7 pg/m³)
SRP 2004
(4.8 ± 5.6 pg/m³)
Swan > SRP (p < 0.05)
RGM (pg/m³)
45
40
35
30
25
20
15
10
5
0
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6

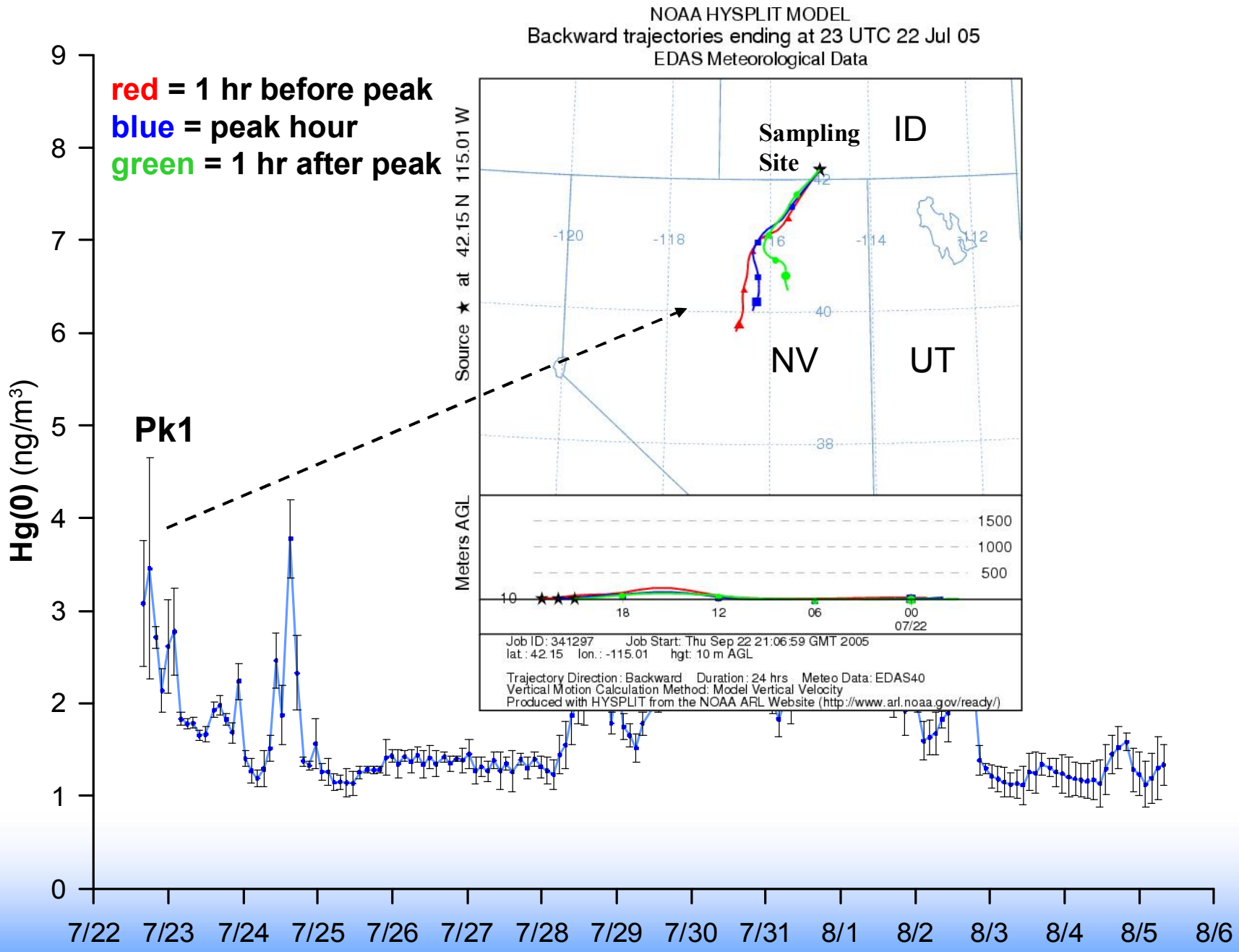

RGM / EGM ratio
EGM (ng/m3)
RGM / EGM ratio
(0.47 ± 0.31%)
Range: 0.04% - 1.4%
0.5% ratio during 8 ng/m3
EGM peak produced
43 pg/m3 RGM peak.
Depressed?
Hg(0) (ng/m3)
RGM / EGM
0
1
2
3
4
5
6
7
8
9
0.01
0.02
0.03
0.04
0.05
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6

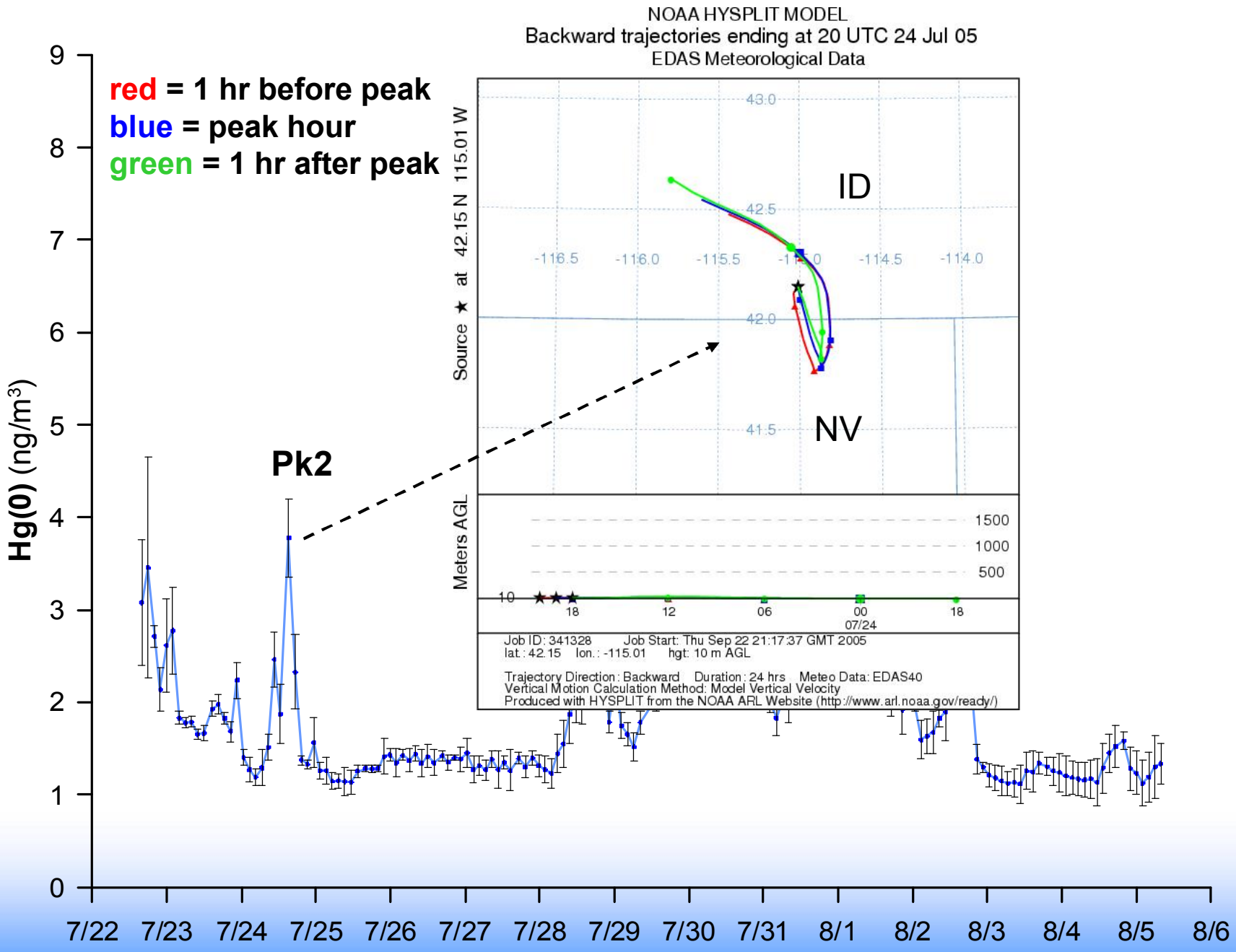
EGM and SO_2

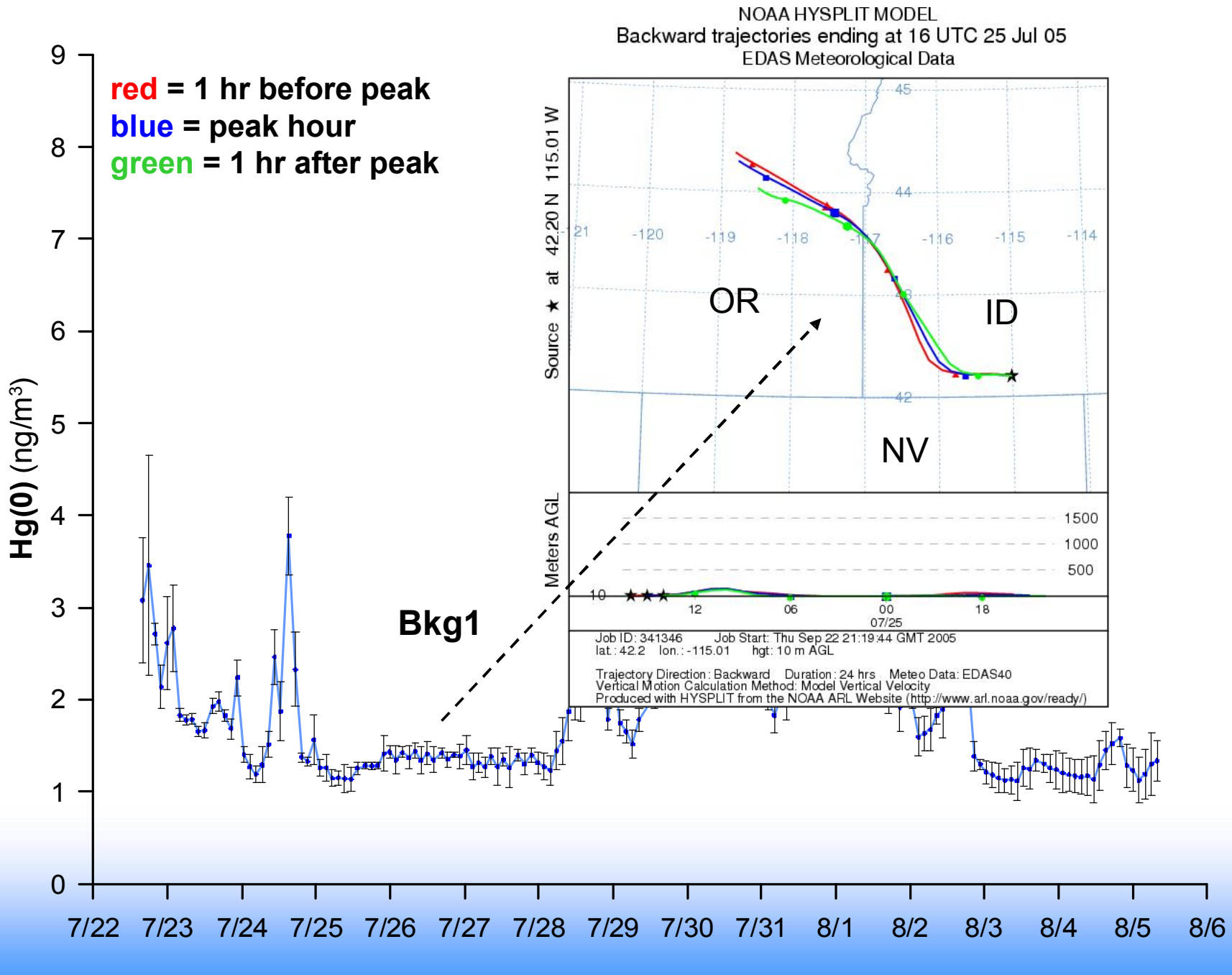


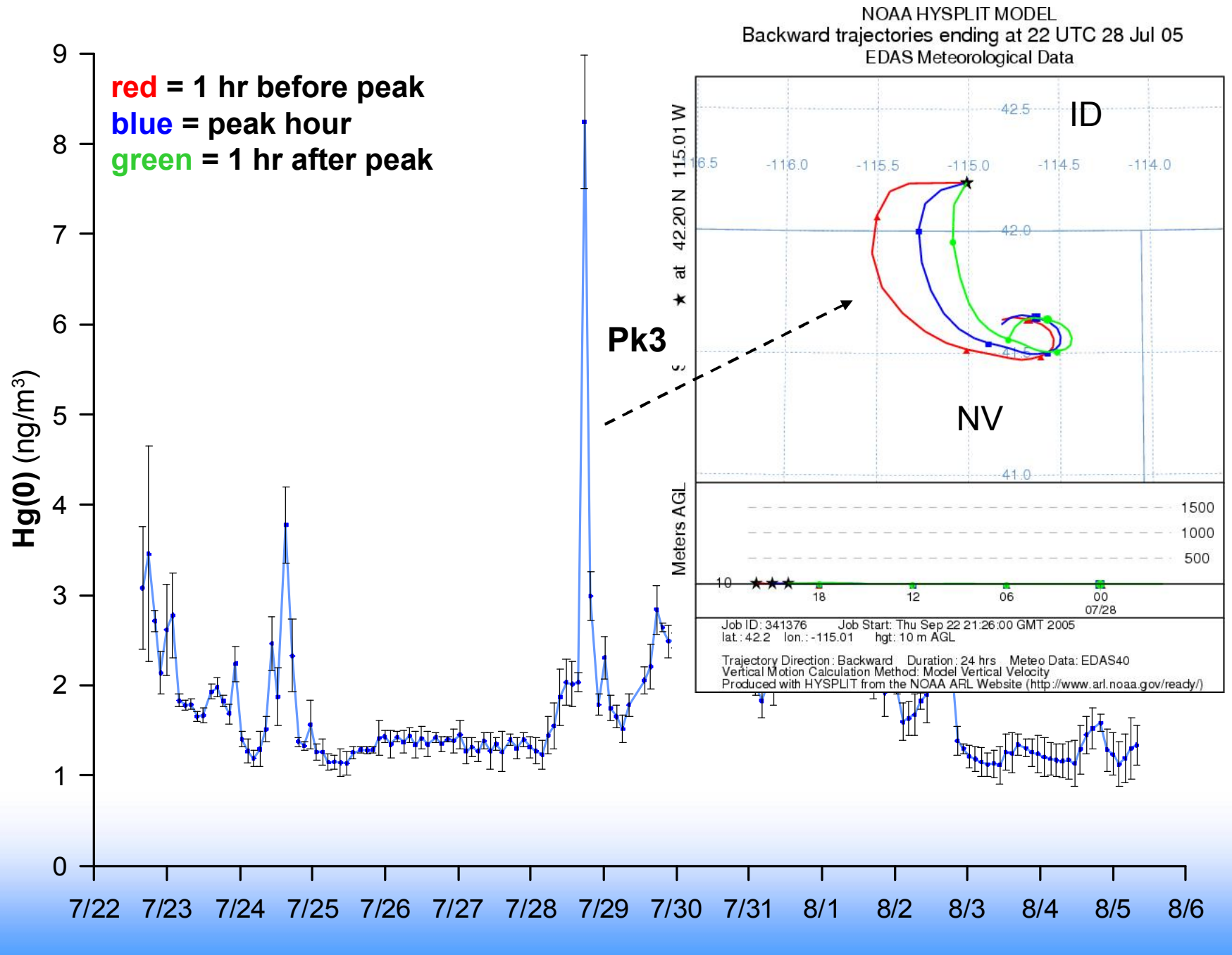
RGM and SO_2

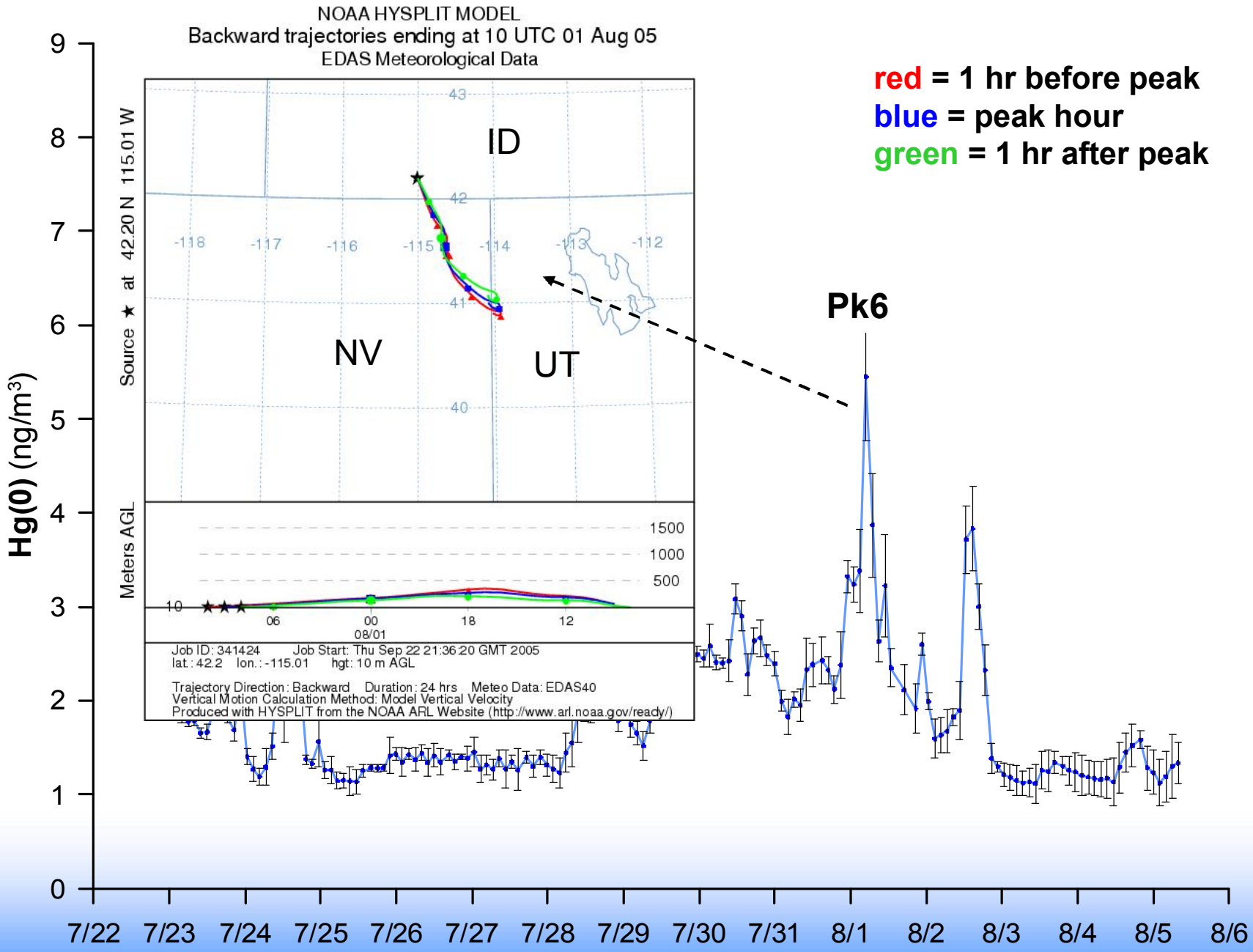


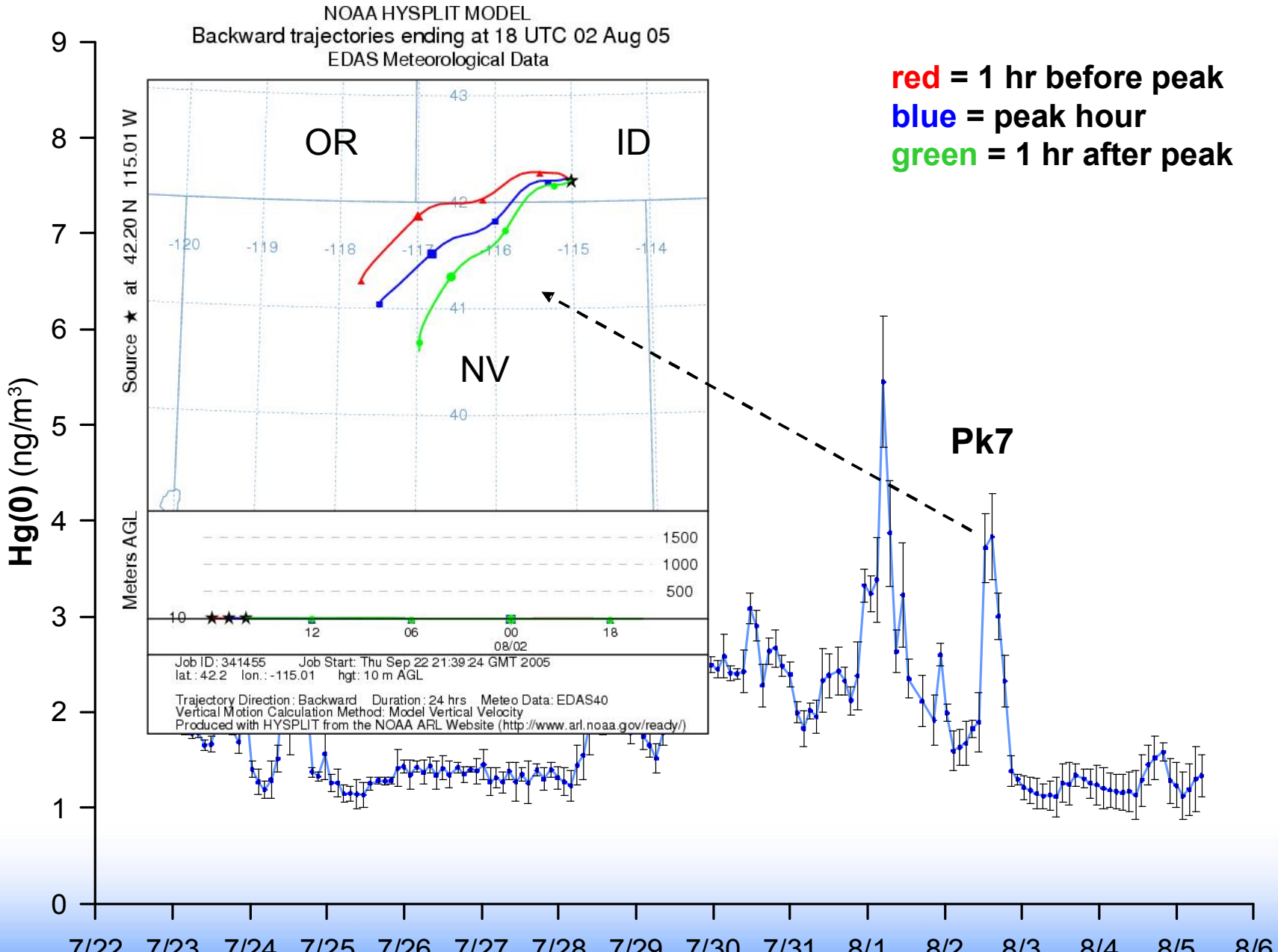

red = 1 hr before peak
blue = peak hour
green = 1 hr after peak
Pk1
Hg(0) (ng/m³)
0
1
2
3
4
5
6
7
8
9
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6
NOAA HYSPLIT MODEL
Backward trajectories ending at 23 UTC 22 Jul 05
EDAS Meteorological Data
Source ★ at 42.15 N 115.01 W
Sampling Site
ID
NV
UT
-120
-118
-116
-114
-112
42
40
38
Meters AGL
1500
1000
500
10
18
12
06
00
07/22
Job ID: 341297 Job Start: Thu Sep 22 21:06:59 GMT 2005
lat.: 42.15 lon.: -115.01 hgt: 10 m AGL
Trajectory Direction: Backward Duration: 24 hrs Meteo Data: EDAS40
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

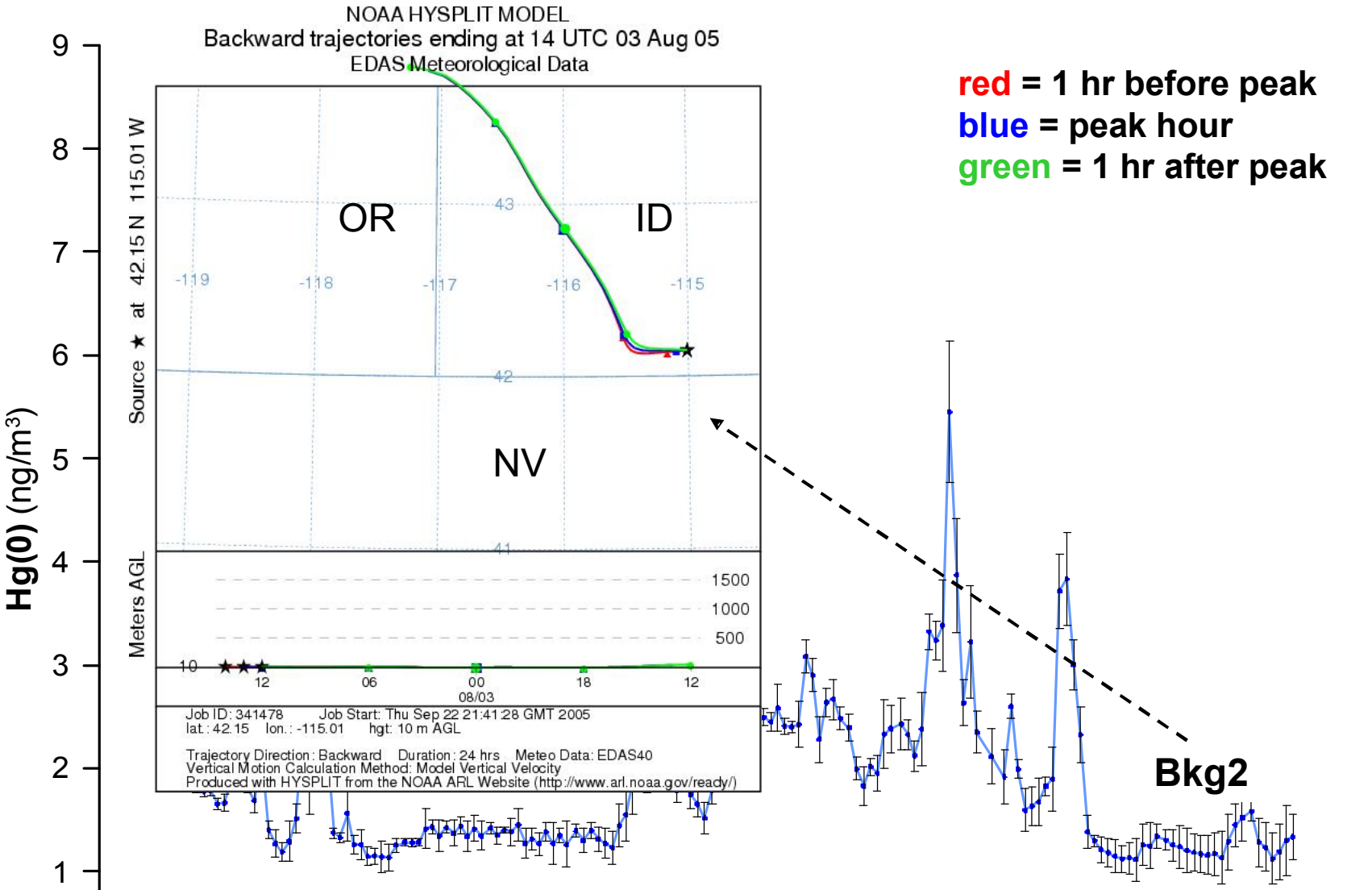

red = 1 hr before peak
blue = peak hour
green = 1 hr after peak
Pk2
Hg(0) (ng/m³)
0
1
2
3
4
5
6
7
8
9
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6
NOAA HYSPLIT MODEL
Backward trajectories ending at 20 UTC 24 Jul 05
EDAS Meteorological Data
Source ★ at 42.15 N 115.01 W
ID
NV
43.0
42.5
42.0
41.5
-116.5
-116.0
-115.5
-114.5
-114.0
Meters AGL
1500
1000
500
10
18
12
06
00
18
07/24
Job ID: 341328 Job Start: Thu Sep 22 21:17:37 GMT 2005
lat: 42.15 lon.: -115.01 hgt: 10 m AGL
Trajectory Direction: Backward Duration: 24 hrs Meteo Data: EDAS40
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


red = 1 hr before peak
blue = peak hour
green = 1 hr after peak
Hg(0) (ng/m³)
9
8
7
6
5
4
3
2
1
0
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6
Bkg1
NOAA HYSPLIT MODEL
Backward trajectories ending at 16 UTC 25 Jul 05
EDAS Meteorological Data
Source ★ at 42.20 N 115.01 W
OR
ID
NV
Meters AGL
1500
1000
500
10
12
06
00
18
07/25
Job ID: 341346 Job Start: Thu Sep 22 21:19:44 GMT 2005
lat.: 42.2 lon.: -115.01 hgt: 10 m AGL
Trajectory Direction: Backward Duration: 24 hrs Meteo Data: EDAS40
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

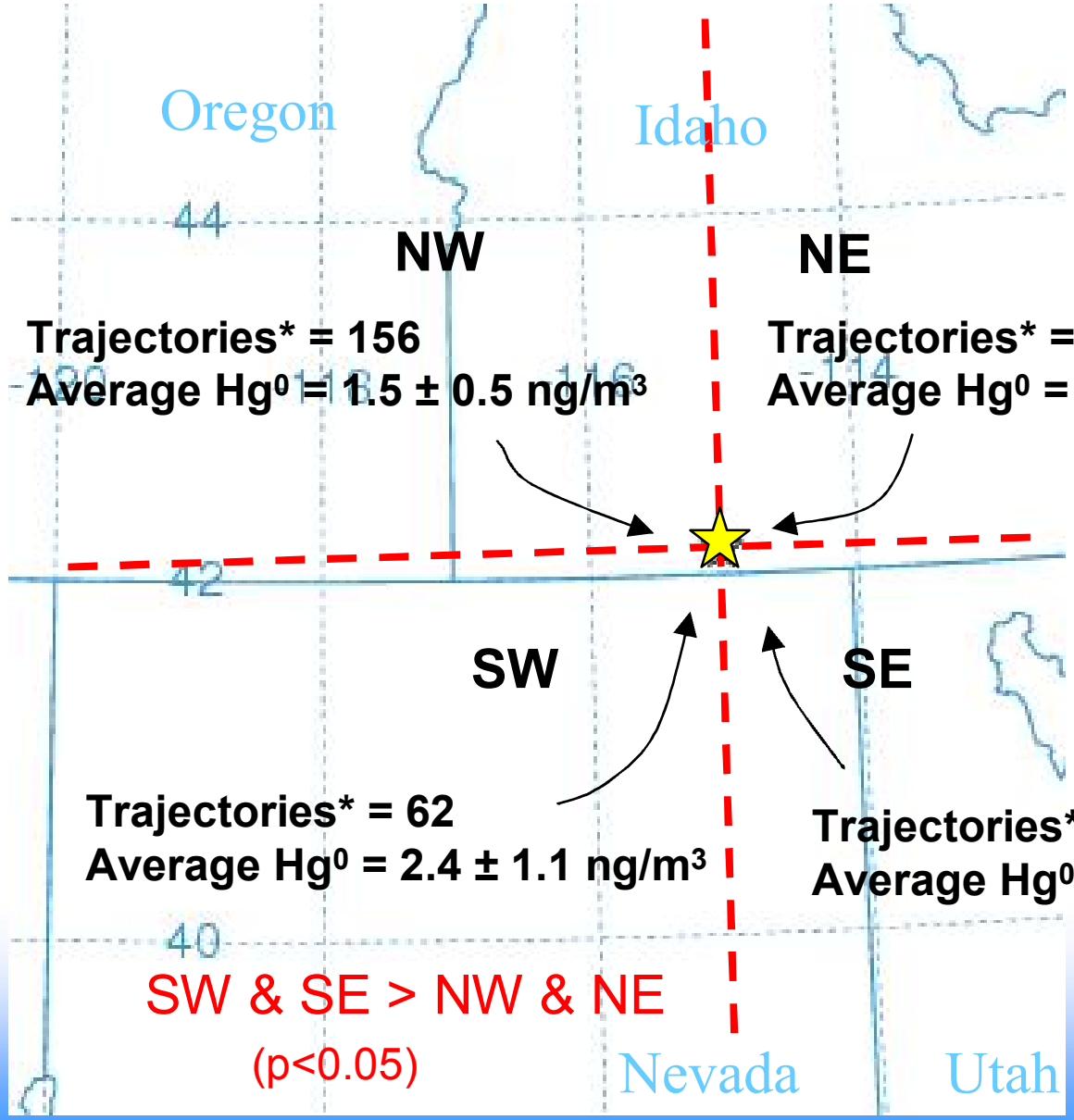

red = 1 hr before peak
blue = peak hour
green = 1 hr after peak
Hg(0) (ng/m³)
0
1
2
3
4
5
6
7
8
9
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6
Pk3
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 28 Jul 05
EDAS Meteorological Data
★ at 42.20 N 115.01 W
ID
NV
42.5
42.0
41.0
-116.5
-116.0
-115.5
-115.0
-114.5
-114.0
Meters AGL
1500
1000
500
10
18
12
06
00
07/28
Job ID: 341376 Job Start: Thu Sep 22 21:26:00 GMT 2005
lat.: 42.2 lon.: -115.01 hgt: 10 m AGL
Trajectory Direction: Backward Duration: 24 hrs Meteo Data: EDAS40
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 10 UTC 01 Aug 05
EDAS Meteorological Data
Source ★ at 42.20 N 115.01 W
ID
NV
UT
Meters AGL
1500
1000
500
06
00
08/01
18
12
Job ID: 341424 Job Start: Thu Sep 22 21:36:20 GMT 2005
lat.: 42.2 lon.: -115.01 hgt: 10 m AGL
Trajectory Direction: Backward Duration: 24 hrs Meteo Data: EDAS40
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)
red = 1 hr before peak
blue = peak hour
green = 1 hr after peak
Pk6
Hg(0) (ng/m3)
0
1
2
3
4
5
6
7
8
9
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6


NOAA HYSPLIT MODEL
Backward trajectories ending at 18 UTC 02 Aug 05
EDAS Meteorological Data
Source ★ at 42.20 N 115.01 W
OR
ID
NV
Meters AGL
1500
1000
500
12
06
00
18
08/02
Job ID: 341455 Job Start: Thu Sep 22 21:39:24 GMT 2005
lat.: 42.2 lon.: -115.01 hgt: 10 m AGL
Trajectory Direction: Backward Duration: 24 hrs Meteo Data: EDAS40
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)
red = 1 hr before peak
blue = peak hour
green = 1 hr after peak
Pk7
Hg(0) (ng/m3)
0
1
2
3
4
5
6
7
8
9
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6


NOAA HYSPLIT MODEL
Backward trajectories ending at 14 UTC 03 Aug 05
EDAS Meteorological Data
Source ★ at 42.15 N 115.01 W
OR
ID
NV
-119
-118
-117
-116
-115
43
42
41
Meters AGL
1500
1000
500
10
12
06
00
18
12
08/03
Job ID: 341478 Job Start: Thu Sep 22 21:41:28 GMT 2005
lat.: 42.15 lon.: -115.01 hgt: 10 m AGL
Trajectory Direction: Backward Duration: 24 hrs Meteo Data: EDAS40
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)
red = 1 hr before peak
blue = peak hour
green = 1 hr after peak
Hg(0) (ng/m3)
0
1
2
3
4
5
6
7
8
9
7/22
7/23
7/24
7/25
7/26
7/27
7/28
7/29
7/30
7/31
8/1
8/2
8/3
8/4
8/5
8/6
Bkg2

Trajectory analysis by quadrant

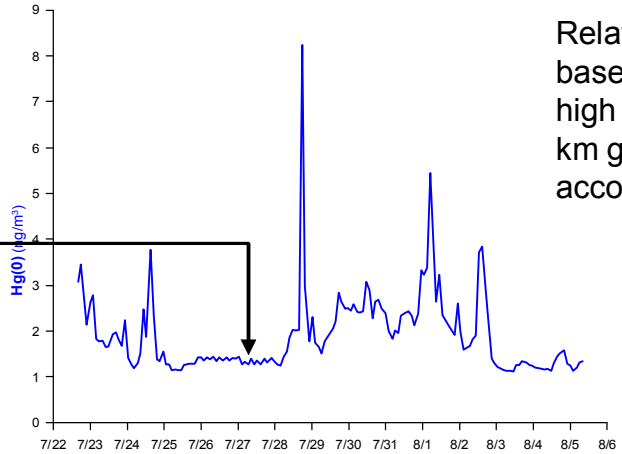


--- Monitoring location

*Trajectories were assigned to a quadrant based on where they spent the majority of time in the previous 24 hours.

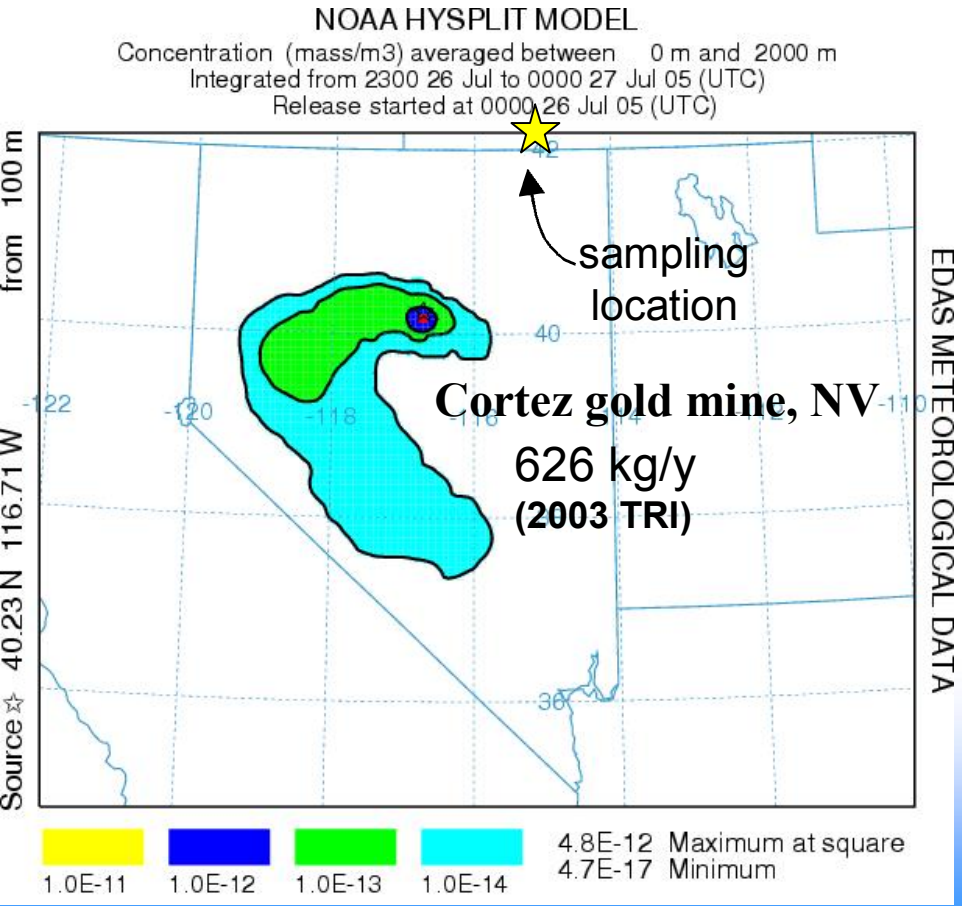
NV Gold mine input?

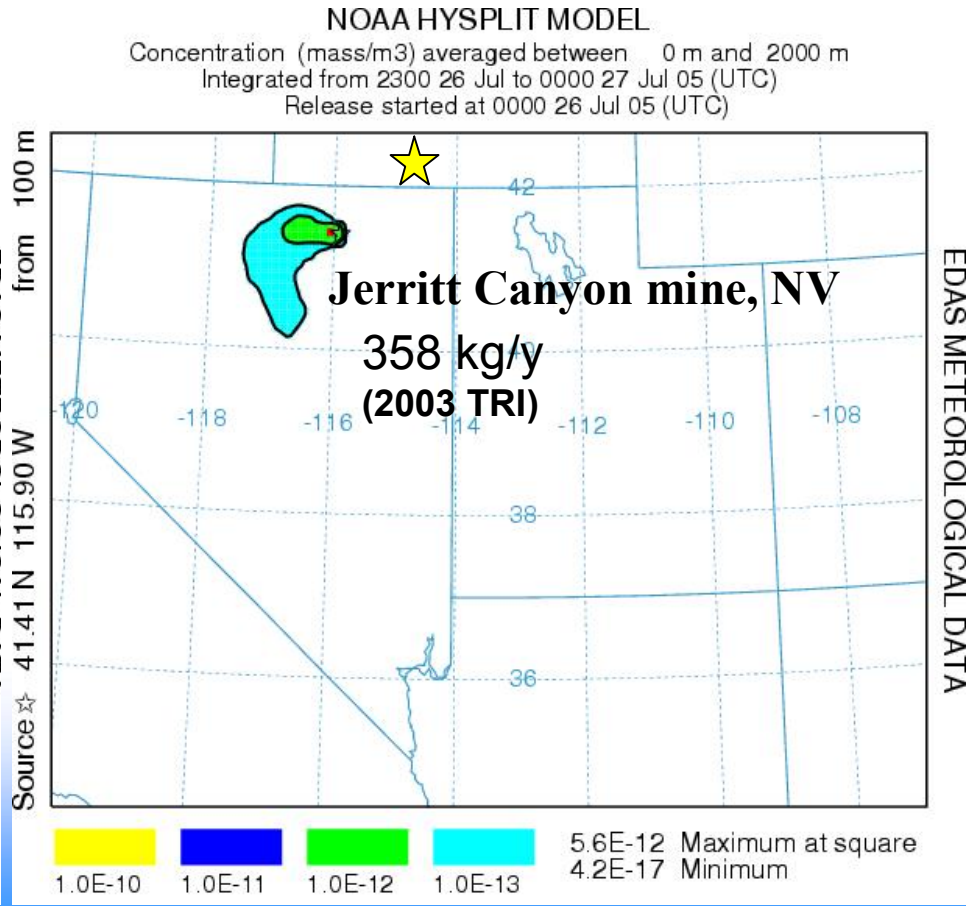
NV Gold mine dispersion during observed background



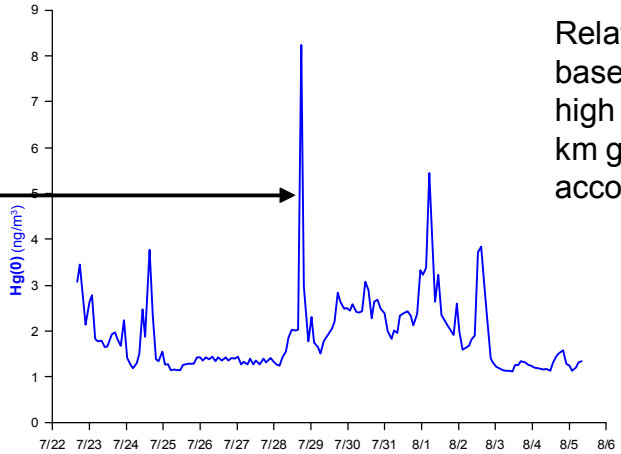
Relative dispersion estimates based on a hypothetical 100-m high unit release. EDAS 40-km grid does not take into account local terrain.

Forward trajectories:

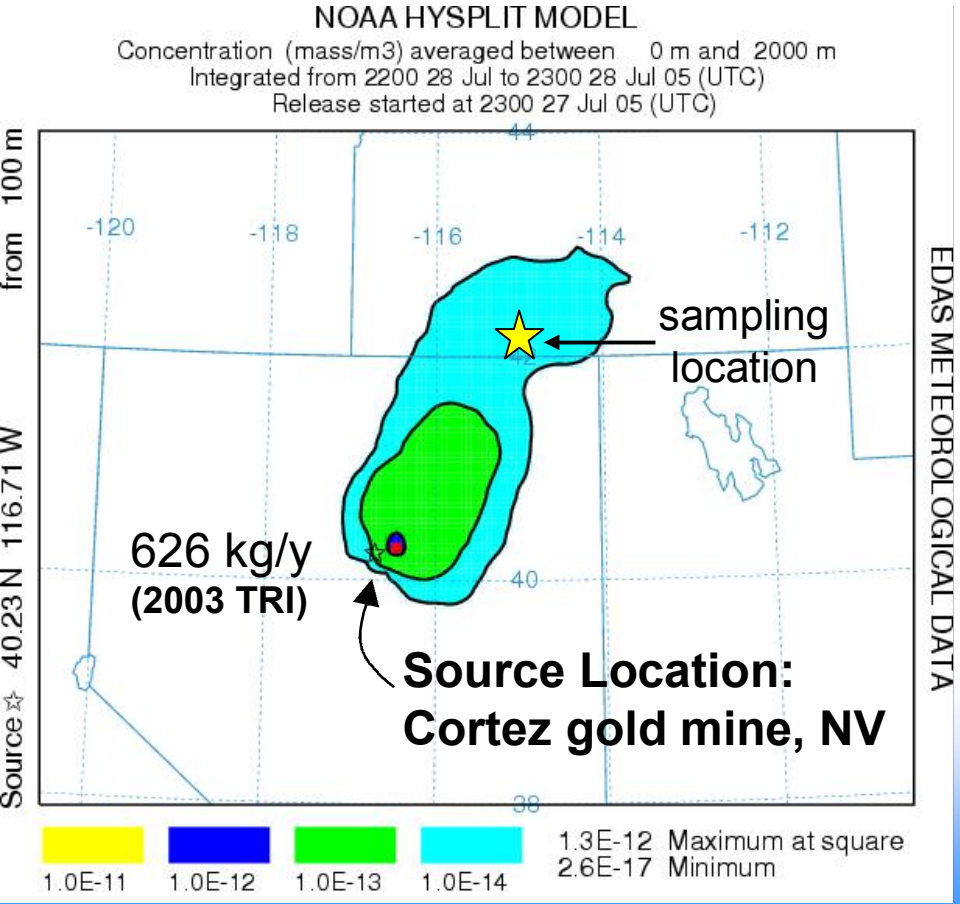


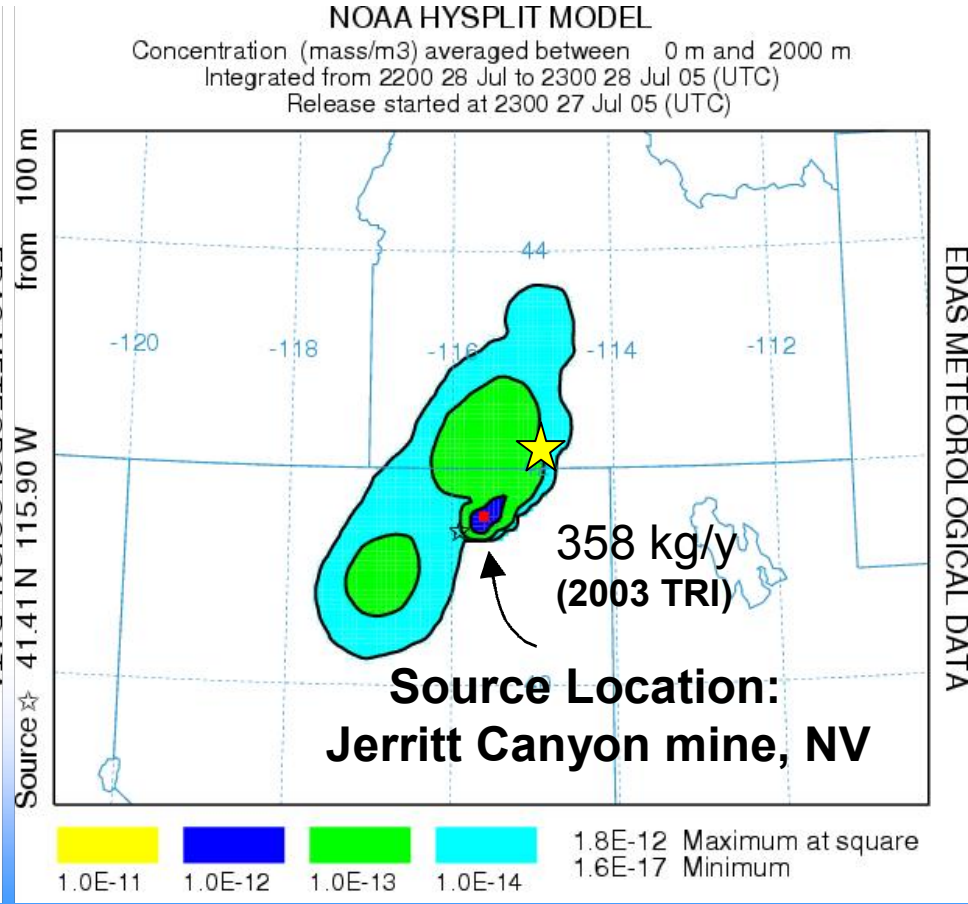


NV Gold mine dispersion during observed 8 ng/m³ peak



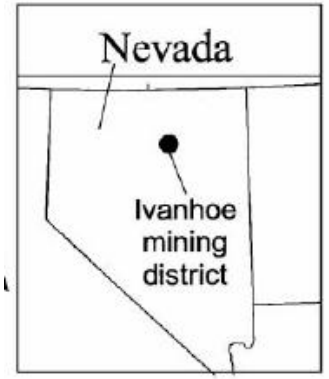
Relative dispersion estimates based on a hypothetical 100-m high unit release. EDAS 40-km grid does not take into account local terrain.





Natural source input?

Largest in vicinity is the Ivanhoe Mining District ~ 50 km SW of Jerritt Canyon Mine and ~ 170 km SW of the sampling location.



78 kg/y Hg emissions estimate over 582 km^2 undisturbed naturally enriched substrate (Engle et al. Atmos Environ 35, 2001)

Hg air concentration averaged over this area:

"box model"

$$C = \frac{\Delta x \, Q_A}{Z_i \, u}$$ (Hanna et al., Handbook on Atmospheric Diffusion)

where

Δx = area source width ~23,000 m

Q_A = area-averaged emission rate - 78 kg/y/582 km^2 = 4.3E-3 ng/m^2/s ~ 15 ng/m^2/hr

Z_i = mixing depth (assume 100 m)

u = annual average wind speed (assume 3 m/s)

C = 0.3 ng/m3 (fully mixed over source – rough estimate)

Dispersion to sampling site (170 km) would reduce this concentration at least 2 orders of magnitude, i.e., non-detectable.

Conclusions

- Average EGM and RGM air concentrations - significantly elevated in the SFCR area compared to background (~ 30 – 70%).
- Elevated RGM concentrations sometimes occurred with EGM peaks, likely due to atmos oxidation. Suggests EGM loading from nearby sources could indirectly increase RGM deposition.
- Elevated EGM and RGM occurred when air parcels came out of SW (Nevada) and WE (Nevada/Utah). Background concentrations occurred when the air was from the NE and NW (Oregon/Idaho).
- Most of the observed peaks were likely from NV gold mine sources--based on their back-trajectories and because these sources are the only ones large enough in the region to produce the peak concentrations observed at our sampling site.
- The relative importance of these short-term peaks for long-term watershed Hg loading (critical factor affecting fish concentrations) is not known – need to better quantify their annual frequency and magnitude compared to that from other sources.